

Presentation highlights: Bionic neurons (BIONs™)

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BIOGRAPHICAL INFORMATION

Dr. Gerald Loeb is Professor of Biomedical Engineering at the University of Southern California (USC) and is Director of the Medical Device Development Facility at the Alfred E. Mann Institute for Biomedical Engineering. He received his MD from the Johns Hopkins University and did one year of surgical residency at the University of Arizona before joining the Laboratory of Neural Control at the National Institutes of Health, where he remained for 15 years. He went on to be Professor of Physiology and Biomedical Engineering at Queen's University in Kingston, Canada, for 12 years, until moving to USC as the first faculty member recruited to the recently endowed Mann Institute there.

He was one of the original developers of the cochlear implant to restore hearing to the deaf and was Chief Scientist for Advanced Bionics Corp. (1994–1999), manufacturers of the Clarion® cochlear implant. He has published approximately 100 refereed journal articles, over half in the field of basic sensorimotor neurophysiology, and holds 33 U.S. patents. He was recently elected a Fellow of the American Institute of Medical and Biological Engineers.

Most of Dr. Loeb's current research is directed toward neural prosthetics to reanimate paralyzed muscles and limbs with the use of new technology that he and his collaborators developed called BIONs™. These injectable, leadless electronic stimulators are now in clinical trials to prevent and reverse disuse atrophy in a variety of neuromuscular disorders and are being further developed to restore functional movement.

PRESENTATION

The development of a technology called BIONs™ (Bionic Neurons) has potential application in prosthetics. BIONs are wireless electrical devices that can be implanted in muscles that require stimulation and at peripheral nerves. They are powered and controlled via radio waves from a small external controller that can be worn by the patient. Within a device the size of a long grain of rice (2 mm wide by 15 mm long) is an integrated circuit chip sandwiched inside an antenna coil. The BION is implanted nonsurgically with the use of a 12-gauge Intracath hypodermic needle.

As a minimally invasive technology, BIONs offer an advantage over functional-electrical-stimulation systems that require surgical implantation of a stimulator or that apply electrical currents at the surface of the skin. BIONs enable therapists to apply currents directly to one or more muscles at widely varying levels of intensity, depending on the clinical need.

When the capacitor electrode of the BION is fully charged, a discharge of that electrode through a controlled current source produces well-controlled stimulation pulses of any intensity—able to stimulate a peripheral nerve or even a relatively large muscle (via its motor axons). BIONs can be modified to produce direct currents, which are being used in experimental methods to promote the regeneration of soft tissue, nerves, and bone. They serve as a flexible means for introducing electrical currents, in many forms of treatment.

BIONs are now being tested in stroke patients at risk for shoulder subluxation (semidislocation). After they are implanted into the two shoulder muscles that pull the shoulder into the socket, electrical current is supplied in

three 15-minute sessions per day to prevent muscle atrophy and excessive stretching from arm weight. The clinician sends the patient home with a transmission coil that is placed over the shoulder region and a simple control box that stores up to three different exercise programs that the patient can self-administer while reading or watching television.

Typical improvements in shoulder joints, after several weeks of treatment, include enhanced “voluntary” movement of the shoulder muscles in some patients. Such stimulation may promote plasticity of the brain and, at a minimum, encourage patients to use muscles that would otherwise be too weak to be functional.

Other potential applications of BIONs include:

- conditioning muscles around the knee in osteoarthritic patients (a clinical trial is underway);
- preventing bedsores, by activating gluteal muscles;
- stimulating and promoting healthy urination and bowel movements by assisting with gastric emptying and respiratory clearing; and
- treating obstructive sleep apnea.

A second generation of BIONs is being developed that would pick up movement and bioelectrical signals from muscles and transmit them to an outside controller, thus expanding the possibilities for restoring functional movements of partially paralyzed limbs by using the patient’s own muscles.

The area of electrical stimulation is one previously bereft of significant clinical application; however, BIONs provide the technology to think outside the traditional “box.” Their modular, generic nature and nonsurgical implantation make it feasible to add new prosthetic functionality at any place and time over the course of a patient’s disease condition. Virtually any physiological and regenerative function of the body that is controlled by electrical currents (i.e., almost everything) can potentially be addressed.

Functionally, BIONs are sophisticated electrical interfaces and implantable Class III medical devices, but they have the potential to be priced and used as a “disposable” product. Because of their small size and their inertness, their removal is not anticipated, even if they are no longer in use. As foreign bodies, they are less intrusive than many surgical materials left internally (e.g., Norplant). Should removal from the body ever be a

necessity, a minor surgery would be required. BIONs are easily visualized by and compatible with all forms of medical imaging including magnetic resonance imaging (MRI).

KEY POINTS

- BIONs can be used to assist or stimulate any body function that is controlled by bioelectrical signals.
- BIONs generate individually controlled stimulation pulses that can produce any desired level of activation even in large muscles such as quadriceps.
- BIONs are “injected,” not implanted, and could remain permanently in the body even after therapy is no longer indicated.

REFERENCE INFORMATION

Citations

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Web Site

<http://ami.usc.edu/Projects/Bion/index.asp>.

[Alfred E. Mann Institute, BIONs]